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ABSTRACT

A research study was conducted to determine the effectiveness of using computer assisted instruction (CAI) to teach handwriting. Designed to take advantage of the computer's facility to rapidly transfer large amounts of precise data, the handwriting program used a computer-connected pen as the interface between learner and machine. Nine boys between 9 and 16 years of age from a special school in Canberra were selected to participate in the study based on the poor quality of their handwriting. Each student attended four 20-minute individual sessions per week in which instruction in handwriting was given using computer equipment, and results indicated that positive results did occur using this technique. One important implication of the data collected from the study was that it was not the use of computers in the instruction process per se which produced significant gains in learning, but rather it was the way in which this instruction was structured. Five references are listed. (LLS)

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COMPUTER-ASSISTED HANDWRITING INSTRUCTION AND VISUAL/KINAESTHETIC FEEDBACK PROCESSES

by

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Despite the recent introduction of technical and computerized communication systems, the importance of being able to handwrite has not markedly decreased. For example, many financial transactions are carried out by credit card but it is still necessary to identify oneself as the owner of the credit with a reliable signiature. This paper argues that instead of computer technology replacing handwriting, it can be used to assist in the teaching of handwriting to people with severe difficulties in this area.

In their review of recent research in handwriting, Peck, Askov and Fairchild (1980) found that a large proportion of those studies were concerned with variations of the two most widely used instructional techniques for handwriting: Copying and tracing. These same two techniques were also used in studies which investigated handwriting development among learning disabled, brain-injured, intellectually handicapped and aphasic children. This comprehensive review revealed little active research in the area of new handwriting instruments and writing surfaces which might be more effective than the techniques of tracing and copying, especially with groups who experience added difficulties in learning to write.

In terms of well established psychological principles of skill acquisition, tracing and copying would not be expected to be very effective teaching techniques. In his discussion on skill acquisition, Welford (1976) has argued that task constraints which involve both accuracy and active decision making on the part of the student will facilitate learning. In addition, it is necessary to have some means by which control of the handwriting behavior is transferred from conscious to unconscious processes so that it becomes "automatic".

In learning to write by copying, the child has to make active decisions about how to form the letter and the sequence of strokes required, although little control over accuracy can be maintained. On the other hand greater accuracy can be achieved with tracing although it is unlikely that much active decision making is required on the part of the learner. Apart from practice at the task, both methods offer little assistance to the learner with respect to transfer of control over handwriting behavior from slower visual feedback processes through to faster kinaesthetic feedback loops and then to more internalized control processes. It is at this last stage of control that a person can be said to be a fluent writer since letter formation is automatic and conscious thought is not required.

The proposal that control of handwriting is not directly mediated by visual feedback is consistent with the earlier finding of Smith and Murphy (1963) that with conditions of modified feedback, handwriting performance was not greatly disrupted when subjects closed their eyes. The fact that Smith and Murphy found an interference effect when delayed visual feedback was presented suggests that visual feedback is not irrelevent but that it is used as a checking mechanism, and that disruption at this level causes the entire skilled sequence to collapse.

It seems that for children who have added difficulties in learning to write, a method is required which gives greater assistance in developing automatic handwriting control processes. Immediate knowledge of results and feedback which gives information to the student which is clearly and simply related to the action and which indicates any discrepencies between what has been achieved and what was required has been suggested by Welford (1976) to be an appropriate method. This type of feedback is quite difficult to achieve in the area of handwriting since the act of fluent handwriting is quite rapid and

yet very complex. Thus, it is necessary to rapidly present quite precise and detailed information to the student, but without distraction from the task at hand.

One of the characteristics of computer technology is the ability to rapidly transfer large amounts of quite precise data. This paper describes an application of computer-assisted handwriting instruction which takes advantage of this facility and which uses a computer-connected pen as the interface between learner and machine. This method of teaching handwriting goes a substantial way to meeting those principles of skill acquisition discussed above.

Method

Subjects

Subjects were 9 boys from a special school in Canberra. Their mean IQ, obtained from school records, was 61 (range = 41 to 81, standard deviation [SD] = 14). They were between 9 and 16 years of age. These students were selected on the basis of their handwriting being the poorest in the school. Other data on academic ability and class rank were not kept by the school.

Apparatus

The apparatus used for computer-assisted training exercises can be seen in Figure 1. The pen and display screen were controlled by a DEC PDP 11/20 computer. The display screen upon which students wrote was 22 cm square and consisted of a 512 by 512 matrix of small but intense neon-orange light points. Each point could be lit or extinguished individually, thus providing a flicker-free, high contrast flat display screen. The face of the screen was angled at about 20 degrees above the horizontal and its leading edge was at desk height.

INSERT FIGURE 1

ABOUT HERE

The pen used in this study was the size and shape of a thick pencil. The pen position was calculated using the lengths of two fine strings which were attached to the pen just above its tip. These strings were lightly tensioned and passed through eyelets at the top of the display. The tip of the pen was spring loaded and operated a switch, located inside the pen body, which indicated whether or not the pen was pressing down on the writing surface. Thus, it was possible to give the impression of writing by leaving a lighted track directly under the tip of the pen as it was pressed down and moved over the screen.

Lower-case manuscript letters and the numerals 0 to 9 (2 to 3 cm high) were used as the test and training materials. The 26 letters of the alphabet were separated into individual files so that circular letters were grouped together, angular letters together and so on. Numerals were presented in various orders in five different files. As may be seen from the letter directly below the pen-tip in Figure 1, complete outlines of the characters to be tracked were not presented to the student, although the complete set of coordinates defining each character was specified by the computer. The use of partial visual cues was used in order to encourage students to make active decisions by requiring them to make predictions about the various alphanumeric forms partly on the basis of their memory of the shapes.

Procedure

Each student attended four 20-minute individual sessions per week. The computer and associated hardware were located in an office adjoining one of the classrooms at the school. The first session was spent familiarizing the student with the display screen and use of the pen. The student was then encouraged to draw with the pen and several simple tracking exercises were introduced.

For the tracking exercises, an outline of a square, called the "cursor-box", was drawn on the display screen directly beneath the pen tip (See Figure 1). As the pen tip was moved around the screen, the cursor-box moved so that it was always under the pen tip. A small blinking spot was located at the point where the child should have the pen tip and as soon as this spot was located within the area of the cursor-box (with the pen pressed down), the blinking spot moved along the track, thickening the line as it went, until it reached a point just outside the leading edge of the cursor-box. In this way, the student completed the tracking task by moving the pen tip, and the cursor-box, along the complete sequence of strokes required to generate the alphanumeric form. Indices of the speed and accuracy of the student's tracking were also calculated.

The difficulty/accuracy of the task could be varied by changing the size of the cursor-box. For example, the task could be made trivial by making the size of the cursor-box larger than that of the letter to be tracked so that placement of the cursor-box over the letter would cause the computer to trace the entire letter in the appropriate sequence without any further pen movements. As the size of the cursor-box was reduced, however, there was a greater correspondence between actual pen movements and model shapes, until when the cursor-box size was the same as the model line thickness complete correspondence was required

for the task to be completed.

In this study three cursor-box sizes were compared with respect to handwriting improvement: large, small, and large reducing to small. In one training condition the size of the cursor-box was 5mm square; for the second 15mm square, and for the third its size was gradually decreased from 15 to 5 mm square. The criterion for reducing the size of the cursor-box, in steps of 1 mm in cursor-box length, was that the student reach an asymptote in terms of speed and accuracy of tracking.

Each student completed two of these training procedures: one condition for letters of the alphabet and a different one for numerals. Thus, three subjects completed the task using a large cursor-box and a small cursor-box (one size for numerals and the other for the letters of the alphabet), three used a large and a reducing size cursor-box and three used the small and the reducing size cursor box. The order and nature of the paired training conditions were balanced. Students were assigned to the various pairings (of training conditions) on the basis of an initial handwriting sample so that all pairings were approximately matched on initial handwriting ability. Alternative training conditions for individual students were given on successive days and the same number of exercises were completed for each condition and student. The length of individual training sessions averaged between 15 and 20 minutes but varied somewhat, since each student completed the same number of tracking exercises per session under two different experimental conditions.

Before training commenced, students were asked to copy each of the lower-case letters of the manuscript alphabet and the numerals 0 to 9. At the end of the four week training program students were again asked to copy the letters of the alphabet and the numerals 0 to 9. Thus, for each student there

were two pairs of handwriting samples: one sample of letters written before and one after the training program, together with a before and after pair of numerals.

These 18 pairs of handwriting samples were given to two teachers, from different schools, who specialized in teaching handwriting to young nonretarded school children. They were asked to rate each pair with respect to the amount, on a 10 point ordinal scale, of improvement shown between the two samples. A rating score of 0, which indicated no difference between the two samples, was allowed. The raters were told that each of the two samples in a pair belonged to the same child but were given no information about either the chronological order of the two or from which training condition they came. The raters were asked to judge the samples in terms of correct formation of letters, hand control, confidence and care displayed, and position of letters on the paper. Both raters had previously scored other handwriting samples for the author and were familiar with the use of the 10 point scale. The two raters chosen for this study were those who, out of a total of eight raters previously used, had the highest inter-rater reliability.

Results and Discussion

As can be seen from Table 1, the greatest improvement in handwriting performance occurred among those students who used a reducing size cursor-box. The average improvement of the second sample, relative to the first, for this group was 4.5 compared to 1.0 for those students who used a small cursor-box, and -0.1 for the group who employed a large cursor-box. A Kruskal-Wallis one-way analysis of variance (Siegel, 1956) showed that these differences, in the ranked amount of improvement as scored by the two raters, were significant ($H = 9.21$, $df = 2$, $p < 0.01$).

. INSERT TABLE 1

ABOUT HERE

Table 1 also shows that the first rater gave somewhat higher scores than the second (an average of 2.1 compared to 1.6), although the correlation between the scores of the two raters was high (Pearson $r = 0.884$, $df = 16$, $p < 0.01$). Both raters commented that the major sources of improvement were in the roundedness and smoothness of the various alphanumeric formations.

An observation which is important was that those students trained with the large cursor-box used gross hand and arm movements to track along the line, whereas students using either the small or reducing size cursor-box tended to employ finer finger movements to guide the pen along the track. This tendency was not great although it was certainly the case that no subject from the group using the large cursor-box was ever observing doing this.

The rank order of group improvement was consistent with the notion that sharpening of the relevant control functions is necessary for improvements in skilled behavior. Smaller amounts of improvement would be expected, under this hypothesis, among those students who used a large cursor-box since this size implies a large degree of error tolerance with the result that students could succeed at the task using only gross and relatively inaccurate hand movements. For students using only a small cursor-box, finer hand/finger movements were necessary to succeed at the tracking task. However, the relatively high difficulty of the task, from the beginning of the training program, resulted in many of these students having great difficulty in performing smooth tracking movements. As a consequence of the small error tolerance (defined by the small cursor-box), many students frequently failed to keep the blinking spot within

the cursor-box but left it behind on the track, resulting in many repeated "back-tracking" movements of the pen. However, some degree of improvement would be expected of this group since, compared to those students using a large cursor-box, there was a greater need for finer control of pen movements to be made in order to succeed at the task.

Among students who used the reducing size cursor-box such back-tracking movements were uncommon. It is suggested that this group improved their handwriting because of the gradual shaping of finer and finer hand/finger movements through successively decreasing the degree of tolerance allowed for successful tracking. Furthermore, this technique (which incorporated the use of partial visual cues, emphasis on speed and accuracy and provision of nondistracting, task oriented feedback), made it easier for the learner to internalize those control functions which are responsible for fluent handwriting.

One of the more salient cues which was gradually internalized was the motion required to form the stroke sequence. This motion was demonstrated to the student by the movement of the blinking spot (when the cursor-box was placed over the spot and the pen was pressed down) from its original position along the prescribed track to a point just outside the leading edge of the cursor-box. Peck, Askov and Fairchild (1980) have discussed research which suggests that motion models are effective means of teaching handwriting to young children. However, the approach described in this study goes further than that mentioned by Peck et al. With this technique, the amount of demonstrated motion was gradually decreased as the cursor-box size was reduced since this size determined the distance between the blinking spot's original position and the leading edge of the cursor-box. Thus, as the learner became more proficient at tracking along the specified tracks, the degree of external cues was

systematically reduced, and the student had to rely more on internalized memory maps of the forms in order to predict the sequence of strokes required to fill in the alphanumeric material.

Hence, a poor student was initially given considerable external support in the task but as the learner became more successful, in terms of speed and accuracy, this support was gradually withdrawn, but in a manner which was not distracting to the learner. It is suggested that one of the advantages of this technique was in its facility to provide task oriented feedback to the student in a way which was not distracting and which was in proportion to the amount of support required for success at the task. It is important to note that feedback was not provided as incentive or reinforcement but rather as information about the relationship between hand/finger movements and the visual representation of letter forms. Thus, the feedback provided by the computer fulfilled the requirement (noted by Welford, 1976) that feedback provide information to the learner that is clearly and simply related to the motor action and which indicates any discrepancies between what has been achieved and what is required before the skill is learned.

Another feature of this technique was that a unique sequence of strokes had to be made for the letter to be "traced". This uniqueness was important since it caused the consistency of the sequence of strokes performed by the student to increase. Inappropriate movements by the student were discouraged by the fact that as soon as the pen was placed down and the cursor-box was over the blinking spot, this spot moved off in the appropriate direction. If the student had little skill at the task, then this movement was large since the cursor-box was large. Thus, the range of possible behavior patterns used to generate a letter form was soon reduced so that the behavior being practiced was more consistent.

As the child completed the tracking task, the model was displayed rather than actual pen movements, although the child's attempt was stored by the machine and if desired could be replayed on the screen, with or without the model track. Displaying the model rather than the student's track was used because of the history of failure that all students in this study had experienced in attempting to learn to write. Comments made by students indicated that this aspect was a major reason for their high motivation and that they appeared to view "their" successful production of the model outline as a sufficient reward for performing the task. Indeed, several teachers commented that after the training program, these students approached conventional handwriting lessons in the classroom more favourably than was previously the case.

Among those students who completed either numerals or letters using the reducing size cursor-box condition, there was no noticiable improvement in the corresponding learning material used with the alternative condition. (It should be remembered that each student learnt numerals under one condition and letters using a different condition). Thus, for example, improvement in forming numerals using the reducing size cursor-box method did not generalize to performance in writing letters in combination with any other training condition. This lack of transfer suggests that what was being learned was knowledge about how to form specific alphanumeric forms, rather than more global techniques related to general handwriting skill

One important implication of these data is that it was not the use of computers in the instruction process per-se which produced significant gains in learning but rather, it was the way in which this instruction was structured. Thus, the value of computer-assisted instruction was greater than simply the novelty and motivational aspects of the machine. It would be profitable to

study the effects of a longer-term program using this technique. At the moment the cost of equipment used in this particular study makes it prohibitive at the level of the classroom, although with the continued development of relatively inexpensive microcomputers, it should soon be possible to change this situation. However, the non-intensive nature of the instruction (20 minute sessions 4 times a week) makes the use of such equipment relevant at the level of specialist educational centers, both in special and regular education. A further application of the general technique of using computers to teach handwriting skills to people with added difficulties is in the area of handwriting for the blind. Such a system would have to be more subtle than that described in this paper since visual feedback could not be used as a starting point for control of the skill. However, Macleod, Jackson and Eulenberg (1980) have described a technique which although at a early stage of development, shows great potential in this area.

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Footnotes

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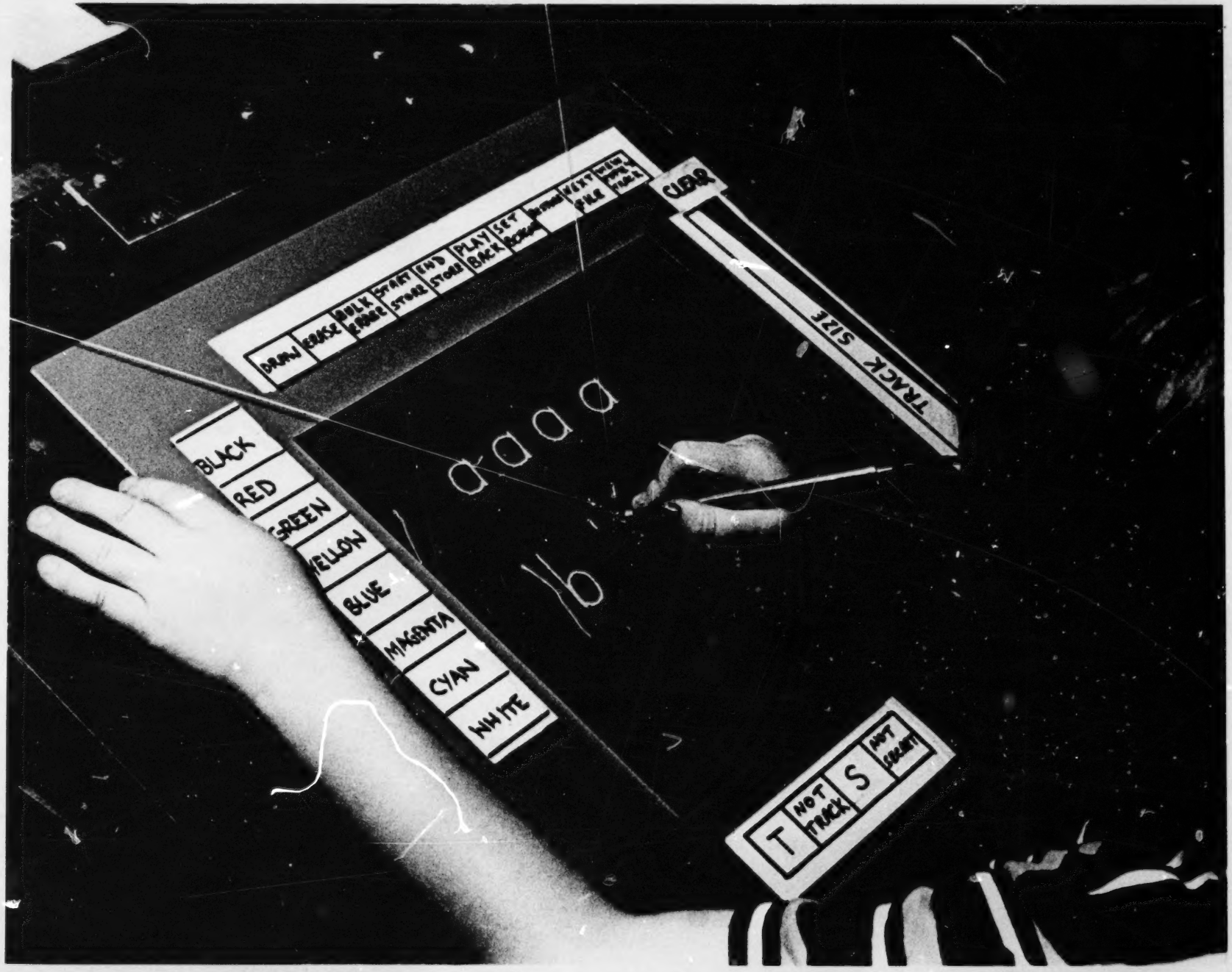
TABLE 1
Improvement of second sample over first for 18 different pairs of handwriting samples~

Training condition	Rater: First	Rater: Second	Rater: Average	Group Average
Large Cursor-box	0	0	0	
	0	-2	-1	
	0	-1	-0.5	
	-1	-2	-1.5	-0.2
	5	5	5	
	-2	-3	-2.5	
Small Cursor-box	3	2	2.5	
	1	-2	-0.5	
	2	6	4	
	-1	-1	-1	1.0
	4	3	3.5	
	-2	-3	-2.5	
Reducing-size Cursor-box	5	5	5	
	1	1	1	
	2	-1	0.5	
	10	8	9	4.5
	4	5	4.5	
	6	8	7	

~ a score of 0 means no perceived improvement and a negative score means that the second sample was judged to be worse than the first.


DRAW
ERASE
BULK ERASE
START STORE
END STORE
PLAY BACK
SET ACCUM
NEXT FILE
CLEAR
TRACK SIZE
BLACK
RED
GREEN
YELLOW
BLUE
MAGENTA
CYAN
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